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Design and Analysis of a Broadband Monopolar Patch Antenna

Awab Fakih
Electronics and Telecommunication
AI Kalsekar Technical Campus
Panvel, India

Jovita Serrao
Electronics and Telecommunication
Sardar Patel Institute of Technology
Mumbai, India

Reena Sonkusare
Electronics and Telecommunication
Sardar Patel Institute of Technology
Mumbai, India

***Abstract*— A new low profile and broadband monopolar patch antenna is proposed. Previously, long rectangular patch antennas were proposed that had a compact structure and high gain, but these antennas were designed for broadside radiation. There are some patch antennas that achieve wide bandwidth by employing a thicker substrate. However, its profile may not be low enough for some cases that cover a very low profile space. We propose a low profile patch antenna with wide bandwidth, high gain and monopole like radiation pattern. The proposed antenna has a bandwidth of 9.4% and gain of 7 dBi with monopole like radiation pattern for an infinite ground plane. While for a finite ground plane bandwidth of 12.3% and gain of 5 dBi is obtained.**

Keywords- Excitation mode; low profile; monopolar patch antenna; coplanar waveguide fed (CPW); omnidirectional; Method of Moments (MoM).

I. INTRODUCTION

Monopole antennas are widely used in wireless communication system, since they can provide omnidirectional radiation patterns [1]. In recent years the demands on mobile communication have grown rapidly. So, indoor wireless networks consisting of numerous indoor base station antennas have been mounted on the ceilings of many buildings and malls, thus there are stringent requirements on an antennas impedance bandwidth and physical size. Many types of monopole antenna are attractive for present wireless communication systems.

A typical monopole antenna is the quarter wavelength monopole antenna, whose length is equal to a quarter of the wavelength at the resonance frequency. The profile of a conventional monopole antenna is too high for some devices that have limited space for hiding the antenna. Microstrip antennas are popular for their low cost, light weight, easy fabrication, mass production and planar structure with low profile [1][2]. Because of the merits it is expected that microstrip antennas can be used to replace monopole antennas that have a high profile of about quarter wavelengths. A microstrip patch antenna in its simplest form consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side. Radiation from the patch can occur from the fringing fields between the periphery of the patch and the ground plane.

This paper is organized as follows. Section I mentions a brief introduction to the applications of monopole antenna. Various methods that have been implemented to design monopolar patch antennas and their drawbacks, is mentioned in Section II. Section III explains the design of a novel low profile monopolar patch antenna. The simulation and results are shown in Section IV. In this section we have also mentioned the effects of a finite ground plane. The paper is concluded in Section V.

II. MONOPOLAR PATCH ANTENNA

Monopole antennas are widely used since they provide a vertical polarization and a conical radiation pattern. However, the profile of a conventional monopole antenna that has a quarter wavelengths is too high for some devices or applications that have limited space for hiding the antenna. Many excitation modes have been studied for circular disc and annular ring patches. A circular microstrip antenna can be used to replace vertical wire monopole [3]. However, the radius of this antenna is very large. Microstrip antennas including ground wire which connects the patch of the antenna to the ground plane can be used to obtain monopole like radiation pattern [4].Such an antenna has total height much less than a quarter wavelength of the centre operating frequency. However, this type of monopolar wire patch antenna has a narrow impedance bandwidth.

To improve the bandwidth a planar rectangular monopole top-loaded with a shorted square or circular patch can be used [5]. The wire monopole and the ground wires [4] can be replaced by a planar rectangular monopole and ground rectangular plates respectively [5]. The profile of such an antenna is around $0.09\lambda_0$, which is much lower as compared to the quarter wavelength dipole. The bandwidth can further be increased by using a circular patch, because of the relatively large patch size. The bandwidth of a probe fed patch antenna is limited by the inductance introduced by the coaxial feed in case of thick substrate. To improve the bandwidth and avoid drilling or soldering of the patch, a L-probe fed circular patch antenna can be used [6]. Such an antenna provides wide bandwidth and high gain with a profile of $0.13\ \lambda_0$. However, such antennas consist of air substrate, which are difficult to implement. Another inconvenience is that such antennas are larger in size as compared to quarter wavelength monopoles. The profile of the L-probe fed circular patch can be reduced to 0.092 λ_0 by shorting the circular patch to the ground plane by four copper wires [7]. The radius of this patch is also reduced due to the presence of shorting wires. The bandwidth can further be enhanced by connecting four trapezoidal plates orthogonally to the circular patch which is shorted to the ground plane by four copper wires [8].

A rectangular planar monopole with a bevel can further increase the impedance bandwidth. Nevertheless, owing to the asymmetry of the planar structure, its radiation patterns in the azimuth plane do not keep omnidirectional as the operating frequency increases [9]. A disk-loaded monopole reduces the profile to 0.08 λ_0. A monopole can also be created by connecting six triangle plates together. The regular hexagon is shorted to the ground plane by six wires [10]. The height of such an antenna is equal to 0.1 λ_0 at resonance frequency. Another type of monopolar patch is the sleeve monopole antenna [11]. This antenna is composed of a circular patch and a disc-conical sleeve, both of which are shorted to the ground plane through four shorting probes. The antenna has a low profile of 0.1 times the free space wavelength of the centre operating frequency. A circular sleeve structure can be added to improve the matching condition of the upper operating frequency edge and thus enhance the bandwidth [12].

The bandwidth enhancement for monopolar patch antennas were demonstrated [3] - [13] with/ without shorting wires. All these antennas have a profile of about 0.1 λ_0 (or even higher); nonetheless it is too thick for some applications such as the installation to an aircraft. Besides these antennas adopt an air substrate and their structures are not simple to be fabricated. A centre-fed circular microstrip patch with a coupled annular ring provides monopole-like radiation pattern [14]. Such antennas have low profile of 0.03 λ_0.

III. Antenna Design

In this paper we propose a coplanar waveguide fed monopolar patch antenna. Fig. 1 shows the geometry of the proposed monopole antenna. The antenna is printed on FR4 substrate with dielectric constant 4.4 and thickness 1.6 mm. The basis of the proposed antenna structure is a rectangular patch monopole, which has dimensions of length L and width W, and connected at the end of the CPW feed-line. The optimized geometric parameters of the proposed antenna are: length of rectangular patch L= 29.63 mm, width of rectangular patch W= 25 mm, ground plane length Lg = 13.12 mm, ground plane width Wg = 14.8 mm, feed-line width Wf =3 mm, slot length L1 = 22.7.5 mm, slot length L2 = 21.53 mm, slot width Ws =2 mm, spacing between ground plane and feed length d = 1.65 mm and spacing between rectangular patch and ground plane s = 1.72 mm. The simulations were performed using IE3D software, a commercial full wave simulator based on Method of Moments (MOM).

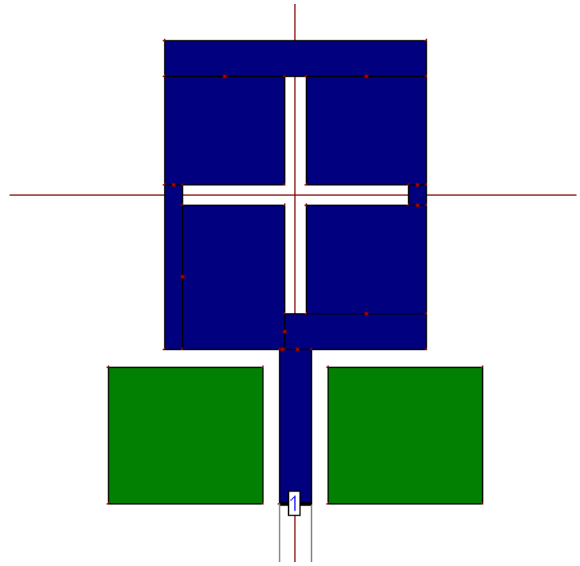

Fig. 1: Geometry of proposed antenna

IV. Results and Discussions

The dimensions for the plus sign on the rectangular patch are finalized using iterative method. The designed monopolar patch has a profile of 0.027λ_0 which is lower than that of a centre-fed monopolar patch [14]. When the patch was simulated with infinite ground plane the following results were obtained. The return loss obtained is shown in figure 2. The antenna resonates at 5.236 GHz. Bandwidth of 9.4% is obtained using the proposed antenna. As shown in figure 3, gain of 6.85 dBi is obtained at the resonant frequency which is much higher than that obtained using circular patch with annular ring. The directivity is shown in figure 4. Directivity of 8.2 dBi is obtained at the resonant frequency.

We have also simulated the antenna for a finite ground plane. The return loss obtained is shown in figure 5. The antenna resonates at 5.236 GHz which is same as the resonant frequency using infinite ground plane. Bandwidth of 12.3% is obtained using the proposed antenna. VSWR is well below 2 in the range 5 to 5.7 GHz as shown in figure 6. As shown in figure 7, the gain lies in the range of 4 to 5 dBi. The gain obtained is almost twice times higher than that obtained by a circular patch with annular ring. As shown in figure 8, directivity lies between 6.5 to 7 dBi. Fig. 9 and 10 depict the radiation pattern of the designed antenna. The proposed antenna has monopole like radiation pattern in the elevation plane and omnidirectional pattern in the azimuth plane. The performance of the proposed antenna with that of the centre fed circular patch with annular ring is compared in table 1. The difference in the return loss for infinite and ground plane is shown in figure 11.

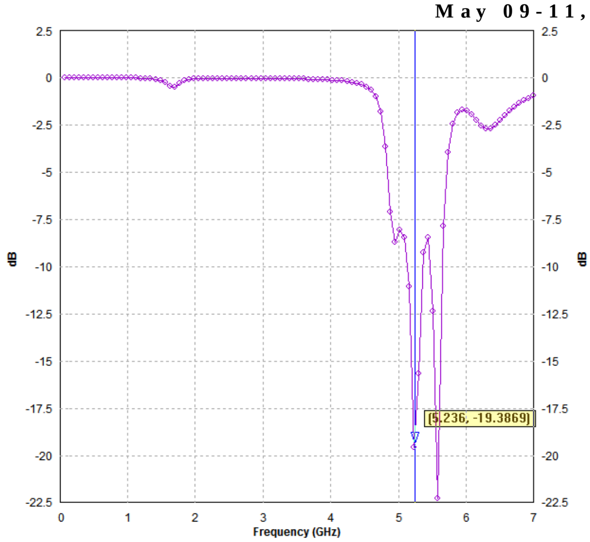

Fig. 2: Return loss of proposed antenna with infinite ground plane

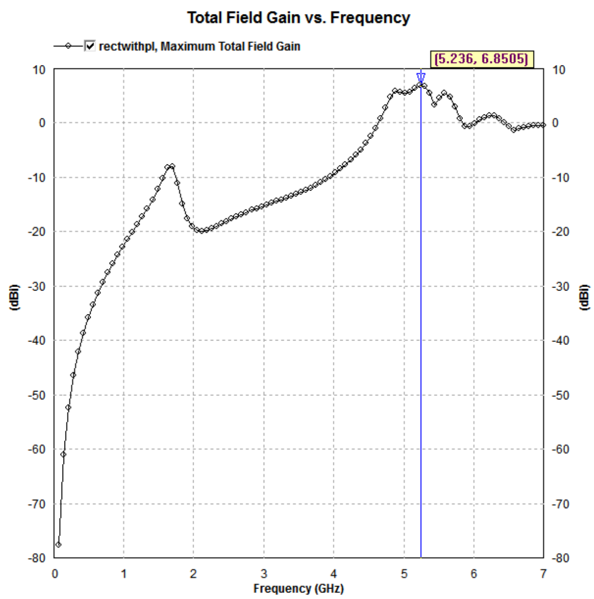

Fig. 3: Gain of proposed antenna with infinite ground plane

V. Conclusions

The proposed broadband CPW-fed monopole antenna with single plus sign has been proposed, designed and simulated for WLAN operations. The simulated results show a bandwidth of approximately 10%. Radiation pattern and gain performance of the antenna is acceptable at all the frequency bands. The performance of the antenna has been compared with that of a centre fed circular patch antenna with annular ring. The designed antenna has broad bandwidth, high gain, monopole like radiation pattern while maintaining a low profile of $0.027\lambda_0$.

TABLE I. Comparision of centre fed circular patch with annular ring with the proposed rectangular monopolar patch antenna

Parameters	Centre fed circular patch with annular ring	Patch with plus sign slot & infinite ground plane	Patch with plus sign slot & finite ground plane
Substrate	RT Duroid	FR4	FR4
Dimensions	Radius = 60 mm	40 mm X 30 mm	40 mm X 30 mm
Resonance	5.6 GHz	5.2 & 5.8 GHz	5.2 and 5.8 GHz
Return loss	-20.92 dB	-21.25 dB	-28.36 dB
Bandwidth	12.28%	9.4%	12.3%
Gain	2.33 dBi	6.85 dBi	5 dBi
Directivity	5.86 dBi	8.2 dBi	7 dBi
Profile	$0.05\lambda_0$	$0.027\lambda_0$	$0.027\lambda_0$

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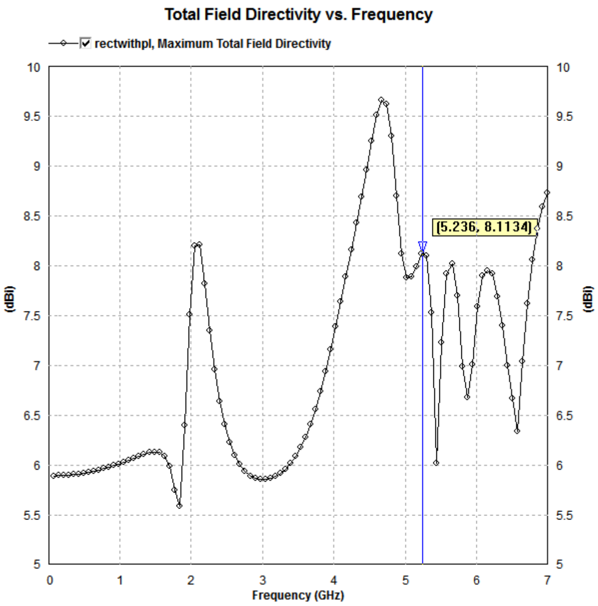

Fig. 4: Directivity of proposed antenna with infinite ground plane

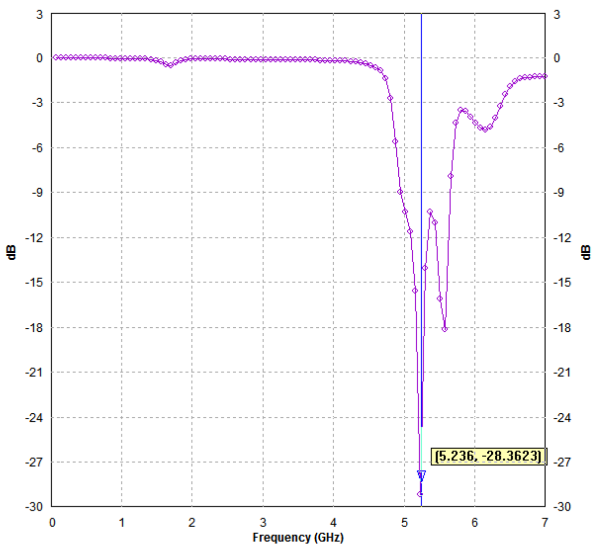

Fig. 5: Return loss of proposed antenna with finite ground plane

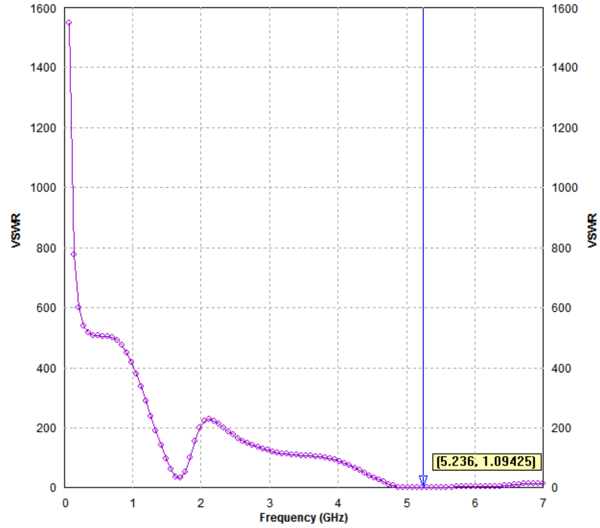

Fig. 6: VSWR of proposed antenna with finite ground plane

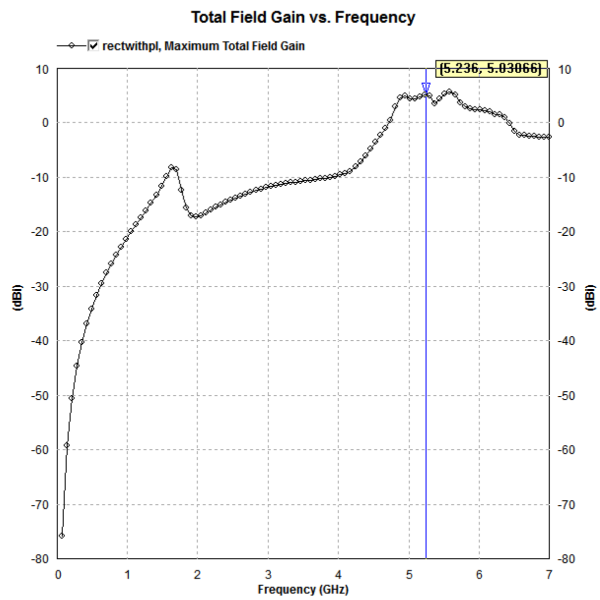

Fig. 7: Gain of proposed antenna with finite ground plane

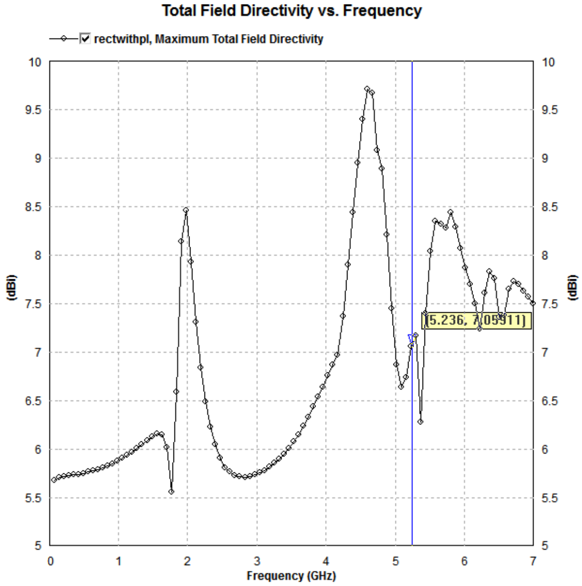

Fig. 8: Directivity of proposed antenna with finite ground plane

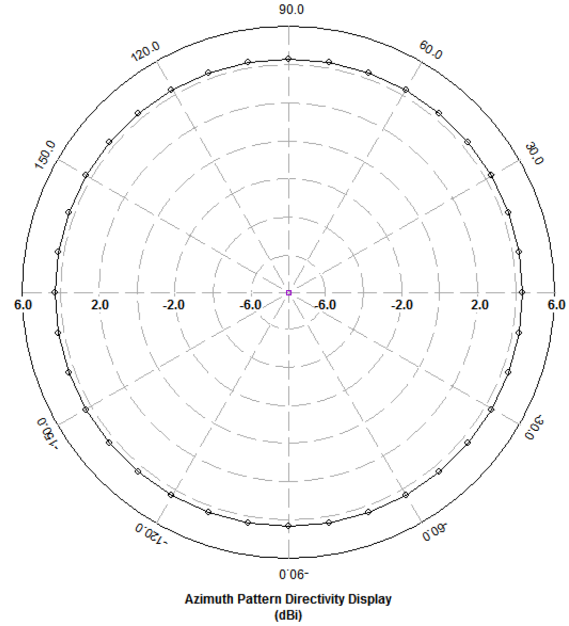

Fig. 10: Azimuth pattern of proposed antenna with finite ground plane

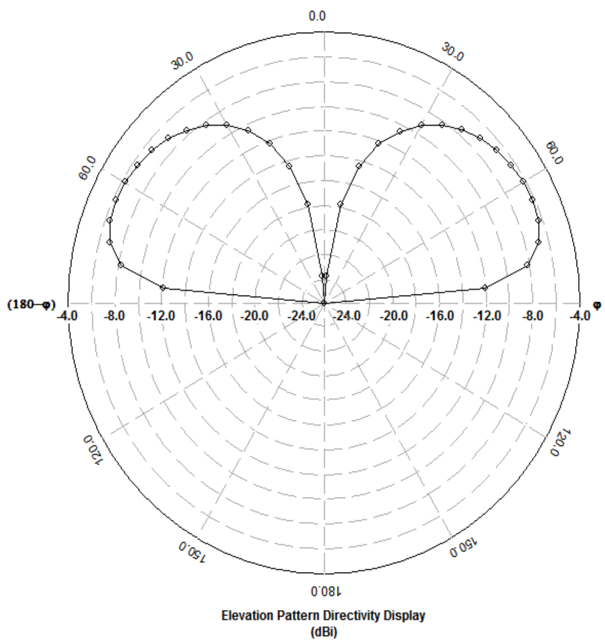

Fig. 9: Elevation pattern of proposed antenna with finite ground plane

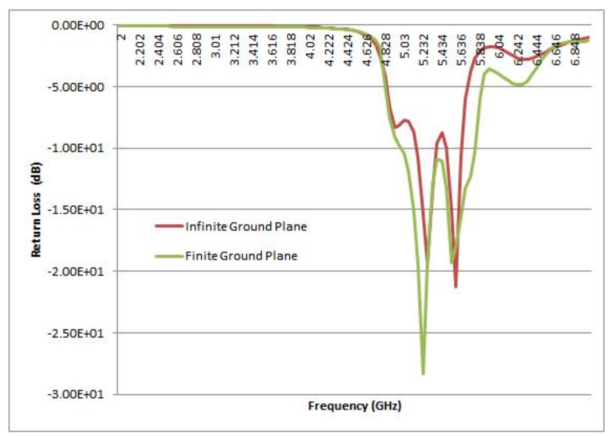

Fig. 11: Return loss of proposed antenna with infinite and finite ground plane